Effect of Temperature and Drying Time on Some Nutritional Quality Parameters of Dried Tomatoes

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Abstract

The causes of losses of farm produce are linked in many complex ways to beliefs and attitudes that underlie traditional ways of managing the past harvest system. Vegetables such as tomato, okra, onion, pepper and their likes are perishable crops which deteriorate few days after harvest. The nutritional values of the dried vegetables examined was assessed using the method prescribed by AOAC. The drying was done at temperature of 30^0C for 1 hour and 6 hours while another drying was done at temperature of 90^0C for 1 hour and 6 hours. The values of the moisture content, vitamin C, protein and β-carotene before drying were 93.2%, 55 mg/100ml, 0.38 g/100g and 32.59 g/100g, respectively. The 2^2 factorial designs were employed in the plus and minus levels of X_1, corresponding temperature at higher level and lower level, respectively, and the plus and minus signs of factor X_2 represent the drying time at higher level and lower level, respectively.

***Keywords**: Moisture content, protein, vitamin C, β-carotene, drying temperature, drying time, factorial.*

Introduction

Fruit and vegetables form an essential part of a balanced diet. They are an important part of world agricultural food production, even though their production volumes are small compared with grains. Fruit and vegetables are important sources of digestible carbohydrates, minerals, and vitamins, particularly vitamins A and C. In addition, they provide roughage (indigestible carbohydrates), which is needed for normal healthy digestion (Studman 1999).

The economical growing of fruit and vegetables is limited in many countries to certain seasons and localities and to meet the demand during the entire year in all areas, the commodities are preserved using different techniques. The causes of losses are linked in many complex ways to beliefs and attitudes that underlie traditional ways of managing the past harvest system. These factors must be carefully examined and understood before new preservation technologies can be successfully introduced.

Technology has enabled exporters to supply markets around the world with high quality product, and in some cases to introduce and develop new markets. This has included introducing new crops and often defining the quality standards for these crops. The agricultural engineer has an important role to play in enabling producers to define and meet quality requirements (Studman 1999).

Vegetables, such as tomato, okra, onion, pepper and their likes are perishable crops which deteriorate few days after harvest. This is mainly due to the high moisture contents and inability to maintain physiological constancy. Therefore, vegetable crops need special attention to prevent all those losses taking place.

Reasonable percentages of harvest usually go into waste annually. Kordylas (1990) estimated this to be about 20-50% of the harvested produce. As such, this has led to various processing works and practices carried out by researchers with a view to minimizing wastages of these vegetable crops.

More so, farmers are not left out of this, as they are deriving different means of reducing this wastage. One of the various means and the most widely used by farmers is sun drying. Due to the awareness generated by the importance of drying vegetables as a way of processing and preservation, several low cost equipments have been developed to take care of the needs of the local farmers in our various communities.

Vegetables undergo tremendous chemical changes once separated from the parent plant until finally spoilage sets in as a result of attack from bacteria, yeast and fungi. This problem of storage may arise from the texture of the food, colour, flavor and respiratory activities. Fruit become sweeter with storage due to either disappearance of acidic contents or the hydrolysis of starch to sugar. Modification of temperature can be used to increase storage life of the vegetables.

High moisture content also contributes to the quality of deterioration and indirectly to a decrease in quantity. Even under the most controlled conditions, the stored produce cannot be guaranteed as mould free. The infestation of mould in the presence of moisture increases the respiration rate of moulds. In the process of respiration, there is liberation of heat and water and therefore, the moisture content of the produce increases, which in turn increases the reaction until the produce spoils. Thus the way out of these problems is converting the fresh produce to suitable forms so that the shelf lives can be extended. Drying is one of such techniques. The effect of temperature and the duration of the drying are essential factors that require intense investigation (Dauthy 1995).

Tomatoes which are produced in a large quantity in the sub-Saharan north of Nigeria are a rich source of vitamin C to human beings. Tomatoes contain 50 mg of vitamin C in every 100 g edible portion. Ihekoronye and Ngoddy (1985) recorded that vitamin C is very essential to the body, because it helps in maintaining collagen health gums and also acids in wound healing. The extent to which some of these nutrients are affected in the course of drying calls for close monitoring if people are to get the demanded value from the dried product. The drying temperature and the duration of drying are critical factors in this regard.

Generally, fruit and vegetables are heat sensitive and therefore present a special problem when drying. Dehydration has to be carried out under carefully controlled conditions. While sun drying is being increasingly adopted in vegetable preservation due to high cost skill required of the artificial drying method, conservation of nutrients is very important in view of the prevalent micronutrient deficiency problems (Onayemi 1981).

The action of applying heat to a material in order to dry it does not merely remove the moisture but can also affect the nutritional qualities of the dried product (Onayemi_1981).

Fruit and vegetables to be dried must be of top quality, drying will preserve most of the original flavor but will not improve food quality (Kardylas 1990). A fresh vegetable is thoroughly washed, preferable in cold water, for which is noted that cold water help to preserve its freshness. The ideal temperature range for drying a vegetable is between 35 ^{0}C and 63 ^{0}C (95 ^{0}F to 145 ^{0}F) and the medium range temperature is about 48^{0}C (120^{0}F) for most fruit and vegetables. Food can become dry quite fast at these temperatures but there is little enzyme loss. Most enzymes are destroyed at the higher temperature of about 60^{0}C (140^{0}F) (Kordylas 1990). The rate of drying depends upon the rate of humidity and size or thickness of the pieces. The range of drying is determined by a range of factors such as external air, temperature, the size of the food pieces been dried and the depth to which the drying tray is packed. Since these factors vary, it is impossible to give an exact drying time for any particular food item.

The objectives of this study are to quantify the losses in those quality parameters during drying and establish appropriate drying temperature and time that will result in optimum retention of the nutritional parameters as well as ensuring storage stability.

Materials and Methods

The nutritional value of the dried vegetables examined has been assessed using the method prescribed by AOAC (1995). The material used for this study is tomato (*Lycopersicon esculentum*) which was obtained from the experimental farm of the department. The tomatoes were cleaned, washed and sorted out. They were sliced to 1 cm thickness and placed inside the drying chamber of the oven.

Results and Discussion

The drying was done at a temperature of 30^0C for 1 hour and 6 hours while another drying was done at temperature of 90^0C for 1 hour and 6 hours, respectively. The experiments were replicated three times for each stage of the drying and the analysis was carried out to ascertain the effects of the factors used on the parameters assessed. The parameters assessed are the moisture content, vitamin C content, protein content and β-carotene content. The results obtained are shown in Table 1.

The values of the moisture content, vitamin C, protein and β-carotene before drying were 93.2%, 55 mg/100ml, 0.38 g/100g and 32.59 g/100g, respectively. The 2^2 factorial designs were employed in the plus and minus levels of X_1, corresponding temperature at higher level and lower level, respectively, and the plus and minus signs of factor X_2 represent the drying time at higher level and lower level, respectively. The measured response y represents the quality parameter remaining after each set of the experiment was carried out.

To provide an estimate of the treatment effect with a sufficient precision, it was decided that a replicate of the experimental programme of three times was ideal. Before running the experiment, it was also felt that day-to-day variability might influence the variance of the observations and so, to project the treatment comparison against this unwanted source of variability, the 2^2 factorial was randomly run once on each of the three days. The 2^2 factorial responses for each of the parameters are given in Table 2.

A test of the hypothesis that no treatment effect was carried out by first postulating the model:

$$y_{ij} = \mu + d_i + d_j + \varepsilon_{ij}, \quad (1)$$

where: y_{ij} are the recorded measurements observed, $i = 1\ldots4$, $j = 1\ldots3$; the d_i are here defined to be the day effects; d_j is the effect due to treatments; the ε_{ij} are independent; $\mu\,(0,\delta^2)$.

The analysis of variance to estimate δ^2 was used, the variance of the observations and finally to test the hypothesis that the treatment effects d_j are all equal to zero. The analysis of variance for each quality parameter is given in Table 3. To test the hypothesis that the treatment effects d_j are all zero, both the treatment mean square and the error mean square are independent estimates of μ^2 and hence their ratio will be distributed as F with degree of freedom (3,6). The observed ratio of $F_{3,6}$ = 4029.64/0.005 = 805,928.00, upon reference to Table 3 of percentage points of the inverted beta (F) distribution. It is found to be the most unusual value since the probability ($F_{3,6} \geq 12.917$) = 0.005.

Table 1. Average value of parameters (dry basis) for tomato at different temperatures and drying time.

Parameter	Drying Time (hour)	Drying Temperature (^{0}C)	
		30	90
Moisture Content (%)	1	89.04	57.40
	1	89.02	57.40
	1	89.04	57.60
	6	46.98	0.40
	6	46.98	0.60
	6	47.00	0.50
Vitamin C content (mg/100ml)	1	45.00	10.00
	1	45.00	10.00
	1	44.50	10.10
	6	7.60	2.40
	6	7.50	2.60
	6	7.50	2.50
Protein Content (g/100g)	1	0.25	2.25
	1	0.25	2.38
	1	0.25	2.25
	6	2.63	5.38
	6	2.50	5.25
	6	2.63	5.50
β-Carotene	1	25.00	19.40
	1	26.00	19.50
	1	26.00	19.30
	6	13.00	6.50
	6	12.50	6.50
	6	13.00	6.40

Hence the hypothesis, all $d_j = 0$, is rejected, while the hypothesis that the day effects $d_i = 0$ is accepted. This is because the observed ratio of $F_{2,6} = 1$ which is far less than the values of the table.

The three degrees of freedom for treatments were separated into individual orthogonal one degree of freedom contracts associated with the mean of X_1, temperature, the mean effect of X_2, drying time, and a measure of the temperature - drying time interaction effect X_1X_2. These contracts can be computed by employing Eq. (2):

$$d_{ij...k} = \frac{1}{r2^{k-1}}\left(\sum\{ij...k\}T\right), \qquad (2)$$

where $\{ij\ldots k\}$ stands for the 2^k elements of plus and minus signs in the appropriate column as observed in Table 3. Table 4 shows the contrast coefficients for factorial effects for the various parameters considered.

Either of the positive or negative signs can be used in the conclusion, for the individual treatment having the greater effect which can be calculated by using Eq. (1). The X_1 (temperature effect) is estimated to be -39.03 and the X_2 (drying time effect) is calculated to be -49.51, while the interaction effects of X_1X_2 are -7.46.

Based of the evidence provided by the 2^2 factorial designs, the effect of temperature on the moisture content is greater than that of the drying time.

This same procedure is also applicable to verify the extent of the effect of drying temperature and drying time on other quality parameters. To test the hypothesis treatment effect on vitamin C, d_j are all zero, the observed ratio of $F_{3,6}$ =1,120.69/0.028 = 40,024.64 upon reference to the table of percentage points of the inverted Beta (F) distribution $\{F_{3,6} \geq 12.917\} = 0.005$. Hence, the hypothesis, all $d_j = 0$, is rejected. The hypothesis that the day effects, $d_i = 0$, is accepted because the observed ratio of $F_{2,6} = 1$ which is far less than the value on the table of percentage points of the inverted Beta (F) distribution. The three degrees of freedom for the treatments where separated into individual orthogonal one degree of freedom contrasts. The computations of these contrasts were carried out using Eq. (2) and the estimations of these effects are displayed in Table 4. On the basis of the evidence provided by the 2^2 factorial designs from Table 2, the effect of temperature on the vitamin C content is greater than that of the drying time.

To test the hypothesis that the treatment effects on protein content, d_j are all zero, the observed ratio of $F_{3,6}$ = 12.90/0.005 = 2,580.00 upon reference to the table of percentage points of the inverted Beta (F) distribution $\{F_{3,6} \geq 12.97\} = 0.005$. Hence the hypothesis, all $d_j = 0$, is rejected. The hypothesis that the day effects $d_i = 0$ is accepted because of the observed ratio $J_{2,6} = 0.90$ which is far less than the value in the table of percentage point of the inverted Beta (F) distribution. The three degrees of freedom for treatments where separated into individual orthogonal one degree of freedom contrasts. The computation of these contrasts was carried out using Eq. (2) and the results are shown in Table 4. Based on the evidence provided by the 2^2 factorial designs in Table 2, the effect of temperature on the protein content is lower than that of the drying time.

To test the hypothesis that the treatment effects d_j are all zero, the observed ratio of $F_{3,6}$ = 205.24/0.143= 1,435.24, upon reference to the table of percentage points of the inverted Beta (F) distribution $\{F_{3,6} \geq 12.917\} = 0.005$. Hence, the hypothesis for all $d_j = 0$ is rejected, the hypothesis that the day effects $d_i = 0$ is accepted because the observed ratio of $F_{2,6}$ = 0.56, which is far less than the value obtained from the table of percentage point of the perverted Beta (F) distribution. Based of the evidence provided by the 2^2 factorial, the effect of temperature on the β-carotene content is greater than that of the drying time.

Moisture Content

The results of the values of moisture content of the dried tomatoes at different temperatures and time are shown in Table 1. The initial moisture content of the tomato before drying was determined to be 93.2% (wet basis). It was also observed that when drying at 30^0C for 1 hour the moisture content decreased from the initial 93.2% to an average of 89.03%, while drying at a higher temperature for the same 1 hour period of time reduced the moisture content to an average of 57.47%. When drying the tomatoes at 30^0C for continuous 6 hours, the moisture content decreased to an average of 46.99%, while at a higher temperature for the same time duration the sample was burn dried. On the basis of the statistical analysis of variance method, it was determined that both drying temperature and time had a significant effect on the moisture content, and the 2^2 factorial designs (Table 2) showed that the effect of temperature on the moisture content is greater than that of the drying time.

Vitamin C Content

Table 1 shows that the average drying temperature value of vitamin C was computed to be 44.83 ml/100ml and 10.03 mg/100ml at 30^0C and 90^0C, respectively, within the drying time of 1 hour, while when increasing the drying time to 6 hours, an average value of 7.53 mg/100ml and 2.50 mg/100ml of drying temperatures of 30^0C and 90^0C, respectively. The value of the vitamin C for the fresh sample was calculated to be 55 mg/100ml. It could be observed that there was a continuous decrease in the value of vitamin C as the drying time and the temperature increased. Hence, the higher drying time and temperature result in the lower value of vitamin C in tomato.

Based on the statistical analysis of variance method, it was determined that both drying temperature and time had a significant effect on the vitamin C content of tomato, and the 2^2 factorial designs showed that the effect of temperature on the vitamin C content is greater than that of the drying time.

Protein Content

The value of protein content in fresh tomatoes before drying was computed to be 0.38 g/100g. An increase in the protein content of the sample was observed when the drying time and the temperature were increased. The values obtained were 2.59 g/100g and 5.34 g/100g for a drying time of 6 hours for the varying drying temperature of 30^0C and 90^0C, respectively.

The behavior exhibited here by protein, as confirmed by USDA (2005), shows that the protein content of a vegetable after drying can be greater than that of the fresh sample which was attributed to the presence of microbes in the sample. Using the statistical analysis of variance method, it was determined that both drying temperature and time had a significant effect on the protein content, and the 2^2 factorial designs showed that the effect of temperature on the protein content is slightly lower than that of the drying time.

β-carotene Content

The average value of *β*-carotene content of tomato before drying was obtained to be 32.5 µg/100g. From Table 1, the results obtained showed a continuous decrease in *β*-carotene content as the period of the drying time and the temperature increased. When drying at 30^0C for 1 hour, *β*-carotene content decreased from the initial 32.5 µg/100g to an average of 25.67 µg/100g while drying at 90^0C for 1 hour showed that *β*-carotene content decreased to an average of 19.40 µg/100g. Also when drying at 30^0C for 6 hours, the *β*-carotene content decreased to an average value of 12.83 µg /100g while drying at 90^0C for 6 hours showed that the *β*-carotene content decreased to an average 647 µg /100g. On comparing this result with that of Negi and Roy (2003), they were found to be similar. Using the statistical analysis of variance method, it was determined that both drying temperature and time had a significant effect on *β*-carotene, and the 2^2 factorial designs showed that the effect of temperature on the *β*-carotene content is greater than that of the drying time.

Conclusion

The quality parameters of dried tomato, as influenced by the drying temperature and time, have been assessed. From the obtained results, it can be concluded that temperature seems to be more critical than the period of drying, as it can be seen from the analysis. When drying at 90^0C for 6 hours, the moisture content of the product was substantially reduced, which seemed to be the appropriate moisture content for storage (Ojiako and Igwe 2008). It can therefore be concluded that the temperature of 90^0C and drying time of 6 hours seemed appropriate for the drying of tomatoes.

Recommendation

A pre-drying operation such as slicing is recommended. This reduces the drying time and prevents the loss of vitamin C from the vegetables. Slicing should also be uniform to ensure uniform drying time and retention of nutrients.

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Table 2. Data for 2^2 factorial designs in three replicates for determination of the parameters.

Parameter	Treatment	Studied Factors		Designed Variables		Response y_i blocking variable days			Total	Average
		Temp. (^{0}C)	Time (hour)	X_1	X_2	i	ii	iii	T_i	$\tilde{y}_i$
Moisture content	I	30	1	-	-	89.04	89.02	89.04	267.10	89.03
	Ii	90	1	+	-	57.40	57.40	57.60	172.40	57.47
	Iii	30	6	-	+	46.98	46.98	47.00	140.96	46.99
	Iv	90	6	+	+	0.40	0.60	0.50	1.50	0.50
					Day Total T_j	193.82	194.00	194.14	G=581.96	
					Day Average $\tilde{y}_i$	48.46	48.50	48.54		$\tilde{y}$ = 48.50
Vitamin C content	I	30	1	-	-	45.00	45.00	44.50	134.50	44.83
	Ii	90	1	+	-	10.00	10.00	10.10	30.10	10.03
	Iii	30	6	-	+	7.60	7.50	7.50	22.60	7.53
	Iv	90	6	+	+	2.40	2.60	2.50	7.50	2.50
					Day Total T_j	65.00	65.10	64.60	G=194.70	
					Day Average $\tilde{y}_i$	16.25	16.28	16.15		$\tilde{y}$=16.22
Protein content	I	30	1	-	-	0.25	0.25	0.38	0.88	0.29
	Ii	90	1	+	-	2.25	2.38	2.25	6.88	2.29
	Iii	30	6	-	+	2.63	2.50	2.63	7.76	2.59
	Iv	90	6	+	+	5.38	5.25	5.38	16.01	5.34
					Day Total T_j	19.51	10.38	10.64	G=31.53	
					Day Average $\tilde{y}_i$	2.63	2.60	2.66		$\tilde{y}$=2.63
β-Carotene	I	30	1	-	-	25.00	26.00	26.00	77.00	25.67
	Ii	90	1	+	-	19.40	19.50	19.30	58.20	19.40
	Iii	30	6	-	+	13.00	12.50	13.30	38.80	12.93
	Iv	90	6	+	+	6.50	6.50	6.40	19.40	6.47
					Day Total T_j	63.90	64.50	65.00	G=193.40	
					Day Average $\tilde{y}_i$	15.98	16.13	16.25		$\tilde{y}$ = 16.12

Table 3. Analysis of variance showing effect of treatment and days on moisture content.

Para-meter	Source of Variance	Sum of squares	Degree of freedom	Mean square	Expe-cted mean square	*F* Ratio
Moisture content	Total $S(y^2)$	12,088.97	11			
	SSq Treatment	12,088.93	3	4,029.64	EMS 1	$F_{3,6}$ = 805,928.00
	Days SSq	0.00000	2	0.005	EMS 2	$F_{2,6}$ = 1.00
	Errors SSq	0.03	6	S^2 = 0.005	σ^2	
	Pooled SSq error	0.04	8	S^2 = 0.005		$F_{3,8}$ = 805,928.00
Vitamin C	Total $S(y^2)$	3,362.28	11			
	SSq Treatment	3,362.08	3	1,120.69	EMS 1	$F_{3,6}$ = 40,024.64
	Days SSq	0.03	2	0.015	EMS 2	$F_{2,6}$ = 1.54
	Errors SSq	0.17	6	S^2 = 0.028	σ^2	
	Pooled SSq error	0.2	8	S^2 = 0.025		$F_{3,8}$ = 44,827.60
Protein Content	Total $S(y^2)$	38.74	11			
	SSq Treatment	38.70	3	12.90	EMS 1	$F_{3,6}$ = 2,580.00
	Days SSq	0.009	2	0.0045	EMS 2	$F_{2,6}$ = 0.90
	Errors SSq	0.031	6	S^2 = 0.005	σ^2	
	Pooled SSq error	0.04	8	S^2 = 0.005		$F_{3,8}$ = 2,580.00
β-Carotene	Total $S(y^2)$		11			
	SSq Treatment		3	205.24	EMS 1	$F_{3,6}$ = 1,435.24
	Days SSq		2	0.08	EMS 2	$F_{2,6}$ = 0.56
	Errors SSq		6	S^2 = 0.143	σ^2	
	Pooled SSq error		8	S^2 = 0.128		$F_{3,8}$ = 1,608.44

Note: Total $S(y^2) = \left(\sum y^2 - \frac{G^2}{r2^k} \right)$; SSq Treatment $= \frac{1}{r} \sum T_1^2 - \frac{G^2}{r2^k}$; Days $SSq = \frac{1}{2}^k \sum T_j^2 - \frac{G^2}{r2^k}$;

EMS 1 $= \sigma^2 + {}^3\!/_3 \sum_{i=1}^{3} d^2.j$; EMS 2 $= \sigma^2 + {}^4\!/_2 \sum_{i=1}^{4} d^2.j$.

Table 4. Contrast coefficients for factorial effects.

Parameter	Row	Contrast		Coefficients	Total Treatment,
		1	2	12	$\frac{1}{r2^{k-1}} \left(\sum \{ij...k\} T \right)$
Moisture Content	1	-	-	+	267.10
	2	+	-	-	172.40
	3	-	+	-	140.40
	4	+	+	+	1.50
Vitamin C Content	1	-	-	+	134.50
	2	+	-	-	30.10
	3	-	+	-	22.60
	4	+	+	+	7.50
Protein	1	-	-	+	0.88
	2	+	-	-	6.88
	3	-	+	-	7.76
	4	+	+	+	16.01
β-Carotene	1	-	-	+	77.00
	2	+	-	-	58.20
	3	-	+	-	38.80
	4	+	+	+	19.40